# *A Paleogeographic History of the Southern Hemisphere*

Isabel Sanmartín (Uppsala, 2002)

There are several conflicting hypothesis on the paleogeographic history of the Southern Hemisphere continents (Scotese et al., 1988; Kamp, 1980). The following account is my synthesis of ideas presented by Scotese et al. (1988), Veevers (1991), Veevers et al., (1991), Lawver et al., (1992), and McLoughlin (2001), as well as other authors.

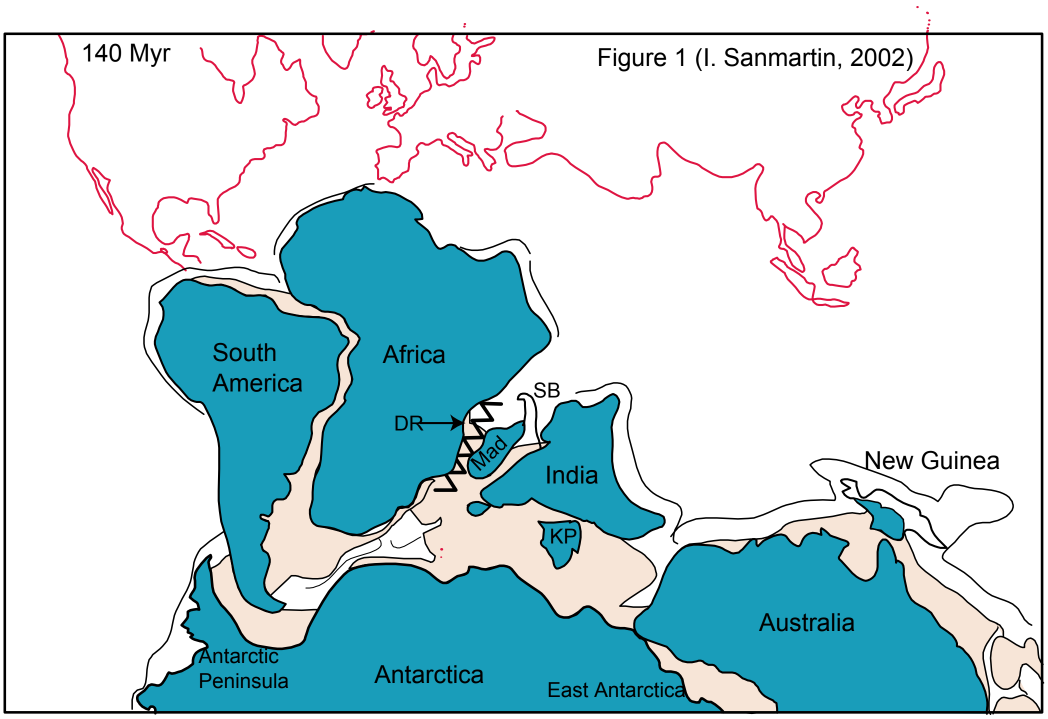


*Figure 1 (200-120 Myr)*.- The southern supercontinent Gondwana was formed by the fusion of several cratons during the Late Proterozoic, following the break-up of the Mid-Proterozoic supercontinent Rodinia. In the Early Triassic, Gondwana and its northern counterpart Laurasia became welded together to form a single landmass, Pangea, surrounded by an ocean, Panthalassa. Although geographically connected, the biotas of Gondwana and Laurasia were partly isolated by a tropical continental zone in the west and the equatorial oceanic gulf of Tethys in the east (McLoughlin, 2001).

The climate of Gondwana was not uniform. Paleobotanists and zoologists (Brenner, 1976; Amorim and Tozoni, 1994; Karol et al., 2000) recognize the existence of two climatic biotic provinces within Gondwana: a “Northern Tropical Gondwana” (northern South America, Africa, Madagascar, India, New Guinea and northern Australia), and a “Southern Temperate Gondwana” province (southern South America, south Africa, Australia, Antarctica, New Caledonia, and New Zealand). We will use this division here instead of the classic geographic separation into West (Africa + South America) and East Gondwana (Australia + Antarctica).

Pangea started to break up in the Middle Jurassic (180-165 Myr), following seafloor spreading in the central North Atlantic between North America and Africa. The initial break-up of Gondwana also started 165 Myr ago, when India began to drift away from Australia-East Antarctica following the activation of the South Atlantic Ridge. At the same time (160 Myr), the continental block formed by Madagascar and India, which was in a northerly position adjacent to southern Somalia, broke away from Africa and started moving southeast along the Davie Fracture Zone. Rifting ended in the Early Cretaceous (121 Myr), when Madagascar attained its present position in front of Mozambique, opening the Somali Basin (Rabinowitz et al., 1983). The separation of Africa and South America began in the Early Cretaceous (135-130 Myr) when the South Atlantic Ocean opened in the far south, at the latitude of Argentine and Chile. This initiated a rotational movement that sent Africa drifting northeast towards Eurasia and South America southwest towards Antarctica (Scotese et al., 1988).

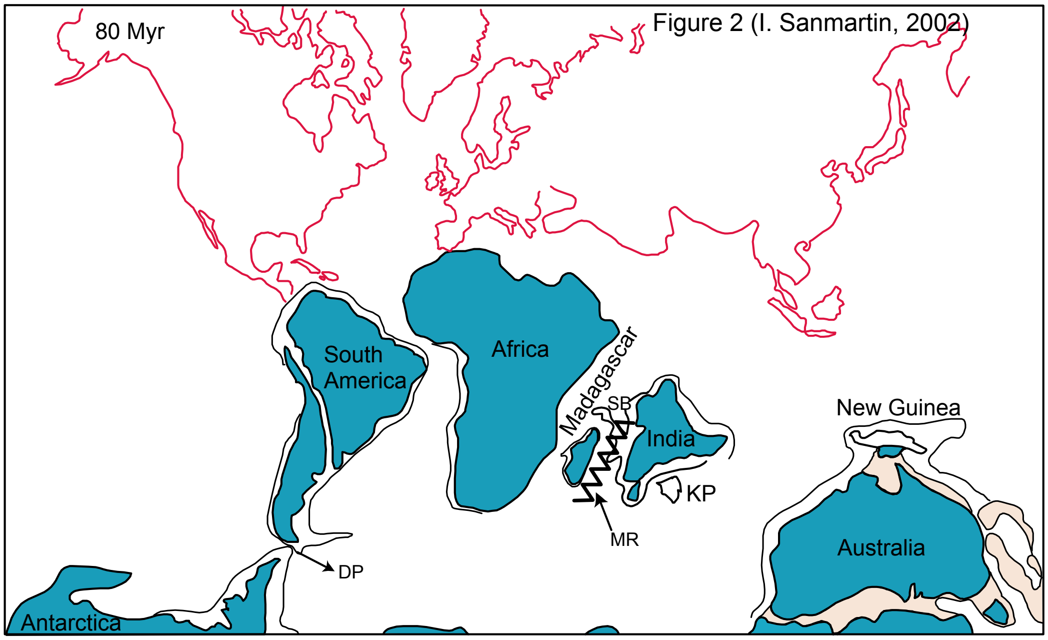


*Figure 2 (110-65 Myr)*.- In the Mid-Late Cretaceous (110-100 Myr), northern South America and Africa began to drift away along a transform fault between Brazil and Guinea opening the central South Atlantic (Scotese et al., 1988). Connections between these two continents, however, could have persisted via volcanic islands on mid-ocean ridges until about 95 Myr (Raven and Axelrod, 1972). Final separation between Africa and Antarctica occurred in the Late Cretaceous (90-85 Myr, Hay et al., 1999), leaving Africa isolated from the rest of the continents until its collision with Eurasia in the Early Tertiary (63 Myr). During the Middle Cretaceous (100 Myr), South America became connected to North America across the proto-Caribbean archipelago, located further to the west than today. Significant biotic exchange between North and South America presumably took place across the Caribbean connection, for example, a first invasion of placental and marsupial mammals

(Springer, 1997; Springer et al., 1998). The connection was broken in the Early Eocene (49 Myr), when the tectonic development of the Caribbean Sea pushed the Caribbean Plate further to the east, into its present position (Hay et al., 1999). During the Cretaceous (100-80 Myr), an epicontinental sea separated the northern and southern part of South America (Johanson, 1998). In the Cenomanian (95 Myr), the subduction of Greater India beneath Eurasia moved India, which was still joined to Madagascar, northwards. At about 88-84 Myr, the spreading Indian Ridge system was captured by the Marion Hot spot south of Madagascar. This triggered the propagation of the nascent Mascarene Ridge to the north, opening the Mascarene Basin between Madagascar and India (Storey et al., 1995). At the end of the Cretaceous (65 Myr), a northward repositioning of the Mascarene Ridge resulted in the separation of India from the Seychelles block. The Seychelles were then transferred to the African Plate, whereas India continued to drift rapidly northward, colliding with Asia around the Early Eocene, 50 Myr ago (Scotese et al., 1988; McLoughlin, 2001).

Figure 3 (I. Sanmartin, 2002)

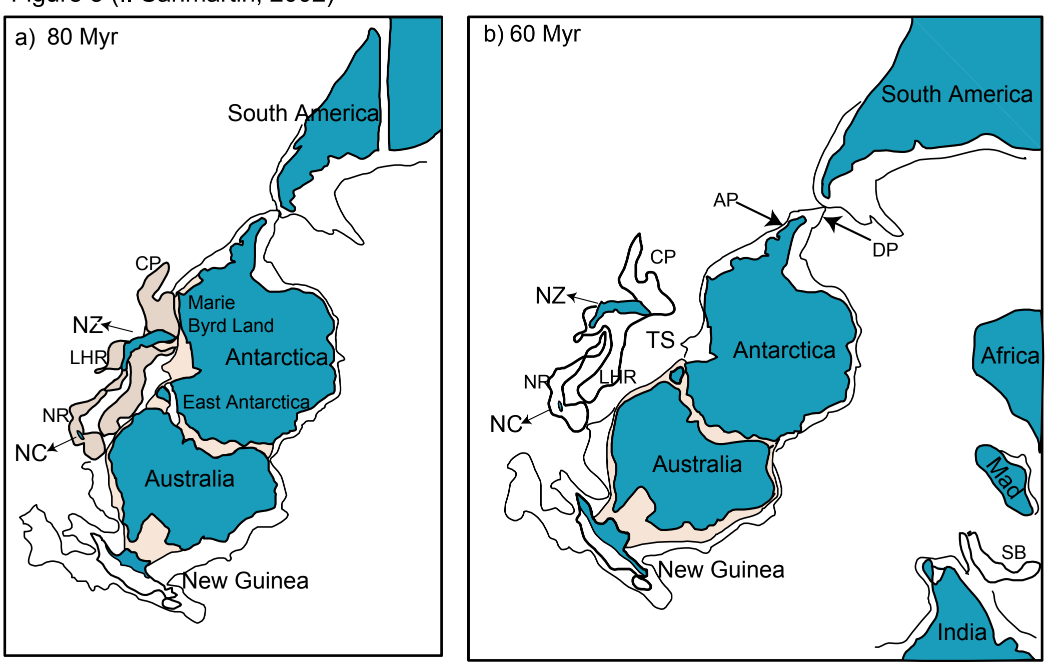

*Figure 3a (90-60 Myr)*.- Up to this period, New Zealand, South America and Australia had not moved from their original positions and were still connected across Antarctica. Southern Australia was adjacent to East Antarctica (Wilkes Land), whereas South America and New Zealand were connected to West Antarctica, trough the Antarctic Peninsula and Marie Byrd Land, respectively. The first continent to break away was New Zealand in the Late Cretaceous. At about 80 Myr, "Tasmantia", the continental block of Gondwana incorporating New Zealand, New Caledonia, the Campbell Plateau, the Lord Howe Rise and the Norfolk Ridge, began to drift away from West Antarctica and move northwest, following sea-floor spreading in the Tasman Sea and South-West Pacific Basin (Veevers et al., 1991). By the Late Paleocene (60 Myr), back-arc spreading in the Tasman Sea had rotated the Lord Howe Rise and the New Zealand Plateau away from Australia. This, together with the foundering of the Campbell Plateau at this time, severed the last terrestrial connections between New Zealand-New Caledonia and Australia (Veevers, 1991). During most of the Paleogene, New Zealand and New Caledonia were progressively submerged under a marine transgression, with probably more than 80% of New Zealand's present area beneath water by the Mid-Oligocene (Brothers and Lillie, 1988; Cooper and Milliner, 1993).

*Figure 3b (60-30 Myr)*.- Australia and South America remained in contact across Antarctica until at least the Early Eocene. In the Late Cretaceous (90-80 Myr), the clockwise movement of South America that followed the opening of the South Atlantic Ocean brought southern South America into contact with West Antarctica. During the Late Cretaceous-Early Tertiary, the Southern Andes and the Antarctic Peninsula became connected trough the Scotia Arc, forming a continuous mountain chain, which, in turn, was connected to Australia across East Antarctica (Woodburne and Zinsmeister, 1982; Veevers, 1991; Lawver et al., 1992). Antarctica had at that time a warm-temperate climate, and was covered by an angiosperm-rich flora dominated by *Nothofagus*. This presumably established a significant dispersal route for the exchange of southern temperate biota between South America and Australia, which persisted during the Late Cretaceous-Early Tertiary (Woodburne and Case, 1996). Rifting between Australia and East Antarctica began in the Late Cretaceous (96 Myr), but seafloor spreading was very slow and both continents remained in contact along Tasmania and the still emergent South Tasman Rise. By about 64 Myr (Early Paleocene), the South Tasman Rise foundered under the ocean, marking the end of land-corridor dispersal between Australia and South America. Stepping-stone (sweepstakes) dispersal was still possible until the Early Eocene (52 Myr), when a shallow marine seaway formed between Australia and Antarctica (Veevers et al., 1991; Lawver et al., 1992). The increasingly cooler climates that developed in Antarctica by the Middle Eocene (46 Myr) further limited any potential overland dispersal (Woodburne and Case, 1996). Fully marine conditions were finally established in the Late Eocene (35 Myr), when the South Tasman Sea opened between Australia and Antarctica, severing the last terrestrial connections between the two continents. Southern South America and Antarctica still remained in contact trough the Antarctic Peninsula until the opening of the Drake Passage at the Eocene-Oligocene boundary (30-28 Myr). This led to the establishment of the Antarctic Circumpolar Current and the onset of the first Antarctic glaciation (Veevers et al., 1991).

(Figure 4. I. Sanmartin, 2002)

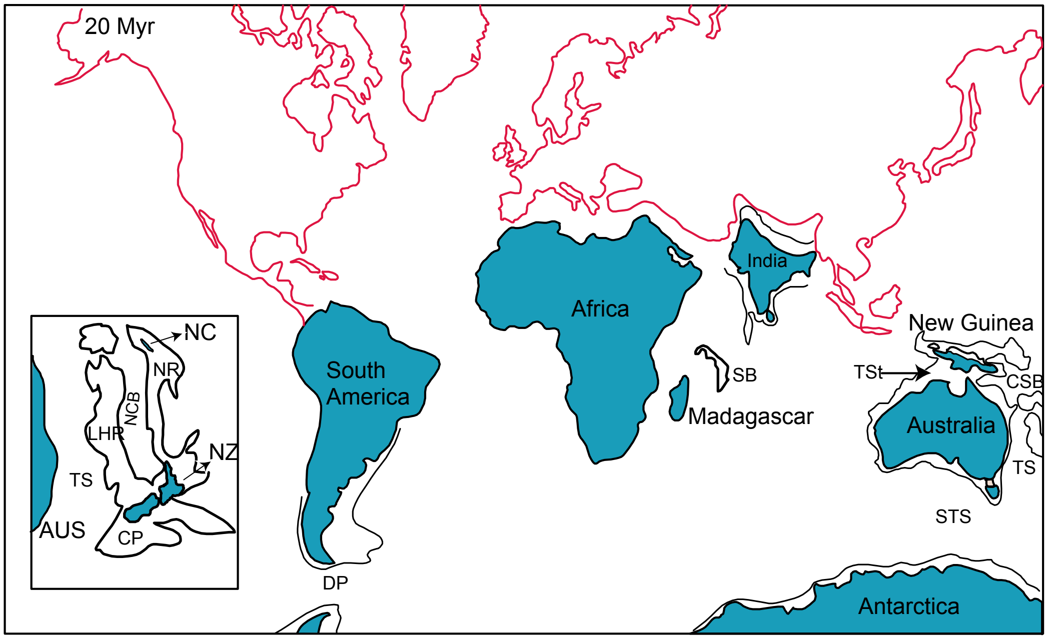


*Figure 4 (40-0 Myr).*- In the Mid Tertiary (40-30 Myr), New Zealand and New Caledonia were finally separated when the Lord Howe Rise and the Norfolk Ridge foundered, opening the New Caledonian Basin (Walley and Ross, 1991). However, a new uplift of the Norfolk Ridge and the Reinga Ridge during the Miocene could have permitted, at least intermittent, land connections between New Zealand and New Caledonia until the Late Tertiary (Herzer et al., 1997).

After its separation from Antarctica, Australia began to drift rapidly towards Asia. During this drift, New Guinea, which was part of the Australian Gondwanan province, formed the northeastern, advancing margin of the Australian Plate. However, only the southern region (the Craton) was emergent at that time. When the Australian and Pacific Plates collided in the Early Oligocene (30 Myr), the Queensland Plateau foundered, opening the Coral Sea Basin; this rotated the Papuan Peninsula into its present position, blocking out the final shape of the north-eastern margin of Australia (Veevers, 1991). As a result of the collision, new island-arc systems were formed northeast of Australia, such as the Melanesian archipelagos of

Fiji, Tonga, Samoa, and Vanuatu (McLoughlin, 2001). In the Late Oligocene (25 Myr), and continuing in the Miocene (20-15 Myr), the collision of the Australian and Asian Plates led to the uplift of the New Guinean lowlands and the accretion of more than 30 terranes of various origins to the northern margin, e.g, the Central Mountain Range (Pigram and Davies, 1987). Following the uplift, tropical groups from South-East Asia invaded the lowlands of New Guinea, and later dispersed into northeastern Australia. A second phase of collision in the Late Miocene-Pliocene (10 Myr) resulted in the uplift of the New Guinean Highlands, as well as high mountain chains in Malaysia, northeastern Australia and New Zealand (e.g., the Southern Alps). This created new montane habitats in New Guinea, which were colonized by southern temperate taxa from east Australia, such as *Nothofagus* (Raven and Axelrod, 1972; Krajweski et al., 2000). During Pleistocene glacial maxima, New Guinea was probably joined to Australia across the Torres Strait by a series of island-arc terranes (McLoughlin, 2001).

Finally, in the Late Tertiary, North America and South America became reconnected, first via the Panama Island Arc in the Mid Miocene (15 Myr, Krzywinski et al., 2001), and later across the Panama Isthmus in the Late Pliocene (3.5 Myr). This established a second period of faunal and floral exchange between North and South America, "the Great American Exchange", with the replacement of the southern marsupial fauna by a second invasion wave of placental mammals. During the Pliocene, Antarctica suffered its last and most severe glaciation with the formation of the East Antarctic ice sheet, which resulted in large-scale species extinction and extreme impoverishment of the biota (Marshall and Coetzee, 2000).